Parasitization of Agonoxena argaula Meyrick (Lepidoptera: Agonoxenidae)

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INTRODUCTION

The coconut flat moth, *Agonoxena argaula* Meyrick, is the most common pest of coconut palms in Fiji. It also occurs in the New Hebrides, the Wallis and Futuna group, the Ellice Islands, Tonga, and Samoa; and arrived in Palmyra and Hawaii sometime prior to 1948. The larva of *A. argaula* is solitary and is usually found on the underside of a leaflet, feeding beneath a silken canopy and leaving elongate brown scars. At Koronivia, about 8 percent of a year-old frond is lost to feeding scars and associated necrosis.

In an attempt to reduce this damage in Fiji, a program of biological control was started in 1958. Since then, parasites have been introduced from Java, New Britain, New Guinea, and Australia by R. W. Paine. The present study was carried out from May 1961 to August 1962 at several points on southeast Viti Levu. The primary objective was to measure indigenous parasitization and thus obtain a basis for evaluating the effectiveness of introduced parasites.

PARASITES AND HYPERPARASITES

Of the six parasites which contribute to the mortality of *A. argaula* in Fiji, four braconids (three indigenous and one introduced species) parasitize the larvae; one tachinid has been associated with the larvae; and a chalcid attacks the pupae (table 1).

These parasites are attacked by various hyperparasites, such attacks being recognized by small emergence holes in the cocoons or, with *Brachymeria*, in the host pupae. The eulophid, *Tetrastichus* sp., apparently attacks all four braconids. The ceraphronid, *Ceraphron fijiensis* (Ferriere); the pteromalid, *Eupteromalus* sp., and the ichneumonid, *Stictopisthus* sp., presumably can develop at the expense of *Apanteles*, the latter hyperparasite attacking the larva of *Apanteles* when it is still in its host. Sometimes a primary parasite of *A. argaula* pupae, the eupelmid, *Eupelmus* sp., is usually hyperparasitic through *Brachymeria, Agathis, Apanteles*, or *Macrocentrus*. The same *Brachymeria* sp. which parasitizes pupae of *A. argaula* has also been reared from cocoons of *Macrocentrus*, puparia of *Tongamyia*, and may be able to attack *Agathis*. Both primary and secondary parasites are sometimes killed by fungi.

Various parasites and hyperparasites associated with *A. argaula* in Hawaii have been recorded since 1948. Van Zwaluwenburg (1949) reared the ichneumonid, *Trathala flavo-orbitalis* (Cameron), from *A. argaula* larvae. This wasp is common on the coconut leafroller, *Hedylepta blackburni* (Butler), in Hawaii and on the rice leafroller, *Susumia exigua* (Butler), in Fiji. Van Zwaluwenburg also observed pupal parasitization by *Brachymeria polynesialis* (Cameron) and described the introduction of *B. agonoxenae* Fullaway from Samoa in 1948. Further introductions were made in 1957 when the larval parasites *Apanteles* and *Bracon* were introduced from Fiji (O'Connor, 1957). Weber (1957) reared *Eupelmus cushmani* (Crawford), and the ichneumonid, *Gelis tenellus* (Say), from pupae of *A. argaula*, but both are most likely to be hyperparasites through *Brachymeria* spp.

TABLE 1.—Parasites of Agonoxena argaula in Fiji

Parasite	Host stage attacked	Recognition of parasitization	Remarks
Braconidae			
Apanteles agonoxenae Fullaway	larva	solitary white cocoon	parthenogenetic
Bracon sp.	larva	two or three white cocoons	average per host: 2.1
Agathis sp.	larva	loose white cocoons within that of host	
Macrocentrus sp.	larva	dark-gray cocoon within that of host	introduced from Java, 1960
Tachinidae			
Tongamyia cinerella Mesnil	larva	puparium within larval skin of host	only at Naduruloulou
Chalcidae			
Brachymeria ?fijiensis Ferriere	pupa	large emergence hole in darkened host pupa	

In his search for parasites to be introduced into Fiji against *A. argaula*, Paine (1958–1961, unpublished reports) studied those attacking other agonoxenids in several Australasian regions. Swezey (1946) also reared two parasites from *Agonoxena* sp. in Guam. Information on these parasites is summarized in table 2.

METHODS AND AREAS

To measure parasitization in Fiji, samples were taken from coconut palms in three areas in southeast Viti Levu. The samples, collected each quarter, were obtained by cutting off those parts of leaflets with cocoons of *A. argaula* or its parasites. These were examined under a binocular microscope in the laboratory and those without emergence holes were dissected. Larval parasitization was based on the entire sample but pupal parasitization percentages were derived from the pupal subsample. This "post-mortem" measurement of parasitization was chosen in preference

TABLE 2.—Parasites of exotic agonoxenids

Parasite	Host stage attacked	Host species	Palm	Location
Braconidae				
**Chelonus* sp.	egg—larva	*Agonoxena* sp.	native	Australia
**Apanteles stantoni* Ashmead	larva	*A. pyrogramma* Meyrick	coconut	New Britain
Apanteles sp.	larva	*Agonoxena* sp.	native	Australia
Macrocentrus pallidus Fullaway	larva	*Agonoxena* sp.	coconut	Guam
**Macrocentrus* sp.	larva	*Haemolytis miniana* Meyrick	coconut	Java
Eulophidae				
**Elachertus* sp.	larva	*A. pyrogramma*	coconut	New Guinea
**Elachertus* sp.	larva	*Agonoxena* sp.	native	Australia
Tachinidae				
**Actia painei* Crosskey	larva	*A. pyrogramma*	coconut	New Britain
Encyrtidae				
Ooencyrtus sp.	pupa	*H. miniana*	coconut	Java
Ooencyrtus sp.	pupa	*A. pyrogramma*	coconut	New Britain
Chalcidae				
Brachymeria hammari (Crawford)	pupa	*Agonoxena* sp.	coconut	Guam

*Parasites released in Fiji

to rearing because the larval parasites attacked their host at various stages. However, certain biases were inherent in the technique. Pupal parasitization was probably underestimated owing to the removal of hosts from the field before they had completed their development and received the maximum exposure to attack. A countervailing bias, leading to an overestimate of larval parasitization, was attributable to the fact that *A. argaula* larvae have a tendency, apparently not shared by the larvae of *Apanteles* and *Bracon,* to drop from the coconut frond prior to pupation. Measurement of parasitization by *Agathis* and *Macrocentrus* was less biased by this behavior, since these two parasites emerge from the host prepupa after it has spun a cocoon. Since there was no reason to assume that these biases varied greatly, it was possible to make relative comparisons between areas, and to lesser extent, between seasons. Similar techniques have been used in studies by H. A. Bess on the coconut leafroller, *H. blackburni,* in Hawaii and by J. P. Harville on the oak moth, *Phryganidia californica* Packard, in California.

The Koronivia samples of *A. argaula* and its parasites were taken from palms, most about 6 years old, scattered along roads, and under shade. In the Nasinu area, the palms were also 6 years old and grew in one grove on a poorly drained slope. In the Suva area the palms were in a single row along the waterfront between the road and a sea wall; most were 15 years old, although some younger ones had been recently transplanted. In all three areas the predominant ground cover was grass. The Koronivia area is 11 miles northeast of the Suva area, the Nasinu area is halfway between.

RESULTS

A total of 1, 536 cocoons, collected at Koronivia, Nasinu, and Suva, was examined during the period from June 1961 through May 1962. Larval parasitization is shown in table 3, with pupal mortality from *Brachymeria* and fungi in table 4.

Apanteles was dominant at Nasinu and *Bracon* at Suva but *Agathis* was rare in both areas. During the study, *Macrocentrus* was not observed in any of the areas but it appeared to be established near a release point between Koronivia and Nasinu. Even at the release point, however, *A. argaula* survival and damage are unchanged.

Brachymeria was the most important source of pupal mortality in all three areas, although consistently less important at Nasinu than elsewhere. To check on the pupal mortality, special collections were made in other areas during July, August, and September 1961. Of 138 pupae examined, 33 percent had been parasitized by *Brachymeria* and 21 percent killed by fungi.

Hyperparasitization percentages were as follows: 868 *Bracon,* 42.4 percent; 476 *Apanteles,* 76.0 percent; 101 *Agathis,* 20.8 percent; and 22 *Macrocentrus,* 63.5 percent. These are probably underestimates since the parasite cocoons, like the *A. argaula* pupae, were sometimes removed before they had been exposed for the normal period of their development. Another cause for underestimating the hyperparasitization of *Agathis* was difficulty in detecting small emergence holes in its loose cocoon. Of 196 pupae parasitized by *Brachymeria,* only eight, or 4 percent, showed evidence of hyperparasitization by *Eupelmus.*

Some observations were made on seasonal variations. In all areas, *Apanteles* was highest in December and lowest in May. At Koronivia,

TABLE 3.—Larval Parasitization

	Locality			Average percentage parasitized
	Koronivia	Nasinu	Suva	
Number examined (Total 1536)	671	487	378	
Percentage parasitized by				
Apanteles	32 %	59 %	17 %	36.6%
Agathis	14	< 1	< 1	6.4
Bracon	25	22	40	27.7
Total	70.8%	81.3%	57.1%	70.7%

TABLE 4.—Pupal Mortality

	Locality			Average percentage killed
	Koronivia	Nasinu	Suva	
Number examined (Total 410)	165	87	158	
Percentage killed by				
Brachymeria sp.	39 %	20 %	40 %	35.4%
Undet. fungi	12	15	21	16.1
	50.9%	34.5%	61.4%	51.5%

Agathis was the opposite, being common in June and sparse in December, which may indicate the existence of competitive interaction. There were no clear seasonal variations with *Bracon, Macrocentrus, Brachymeria,* or the hyperparasites.

Sources of *A. argaula* mortality other than parasitization include predation and disease. Ants occasionally attacked pupae and may have eaten eggs; salticid spiders sometimes caught adults. Larvae, however, were rarely attacked by either ants or spiders. Fungi not only infected pupae but also killed some larvae and adults.

DISCUSSION

Since predation and disease were much less important than parasitization, it is possible to make rough estimates of *A. argaula* survival from the percentages given in tables 3 and 4. The average survival was 14 percent at Koronivia, 12 percent at Nasinu, 17 percent at Suva, and 14.2 percent for all three areas considered together.

Although parasites contribute greatly to the mortality of *A. argaula* in Fiji, their effectiveness is limited. To be fully effective, a parasite should: 1, be able to frequent a wide range of coconut environments; 2, readily parasitize *A. argaula*; 3, compete successfully with other other parasites; 4, be free from attacks by hyperparasites.

Apanteles fulfills the first three criteria but not the fourth, its hyperparasitic burden being quite heavy. If *Apanteles* can account for 37 percent larval mortality despite 76 percent hyperparasitization, how much more could it add if it were free of attack by hyperparasites? The effectiveness of *Bracon*, *Agathis*, and *Macrocentrus* is also reduced by hyperparasites. *Agathis* and *Macrocentrus* may be further restricted by competition and by narrow tolerance to differences in coconut environments. Failure to frequent coconut palms may explain the rarity of parasitization by *Tongamyia cinerella* and the apparent absence of attacks by *Trathala flavo-orbitalis* in Fiji.

In order to reduce the survival of *A. argaula* below the 14 percent level, it will be necessary to introduce parasites which are more effective than the Javan *Macrocentrus* and the species native to Fiji. Of those studied by Paine, the New Britain tachinid, *Actia painei*, appears to be the most promising. It should be able to develop in *A. argaula* and should not be susceptible to attacks by the hyperparasites associated with the present complex. However, Paine observed that it is not uniformly distributed in the coconut areas of New Britain, so it may not do well under Fijian conditions. Since no egg or egg-larval parasites have been recorded from *A. argaula* in Fiji, the Australian *Chelonus* might do well but, as Paine notes, it would have to adapt to the coconut environment. It would be able to compete with the native parasites if they either avoid, or cannot develop in, caterpillars which it has parasitized. However, it would probably be heavily hyperparasitized. The most promising of those species which have not been introduced are the encyrtid pupal parasites in Java and New Britain, but Paine reported that they may be hyperparasitic through *Macrocentrus* and other larval parasites. Introduction of an encyrtid would not be justified unless the encyrtid was a far more efficient pupal parasite than the *Brachymeria* already in Fiji.

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